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Safety and usability of marked cycle lanes

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Background

In Germany, advisory cycle lanes or mandatory cycle lanes have been introduced increasingly for cycling traffic in recent years. Whereas mandatory cycle lanes are reserved for cyclists exclusively, advisory cycle lanes can also be used by other road users when they need to. Vehicles are also allowed to stop in advisory cycle lanes but not to park. In terms of subjective and objective road safety, both of these types of cycle lanes are often the subject of controversy. Some say that drivers can see cyclists well when they use these lanes; others point out that cyclists using them often do not feel very safe.

In a research project commissioned by the UDV (German Insurers Accident Research), the Department of Road Planning and Road Operation (Fachgebiet Straßenplanung und Straßenbetrieb) at TU Berlin conducted an in-depth study of these marked cycle lanes.

Methodology

In Germany, advisory cycle lanes or mandatory cycle lanes have been introduced increasingly for cycling traffic in recent years. Whereas mandatory cycle lanes are reserved for cyclists exclusively, advisory cycle lanes can also be used by other road users when they need to. Vehicles are also allowed to stop in advisory cycle lanes but not to park. In terms of subjective and objective road safety, both of these types of cycle lanes are often the subject of controversy. Some say that drivers can see cyclists well when they use these lanes; others point out that cyclists using them often do not feel very safe.

In a research project commissioned by the UDV (German Insurers Accident Research), the Department of Road Planning and Road Operation (Fachgebiet Straßenplanung und Straßenbetrieb) at TU Berlin conducted an in-depth study of these marked cycle lanes. separating them from the roadway for motor traffic (3 km). The latter are similar to the “protected bike lanes” found in the US or Australia. However, since this was just a small sample of very old cycling facilities, the results for this group are not described or interpreted in this document (see the in-depth research report [UDV 2019] for more information).

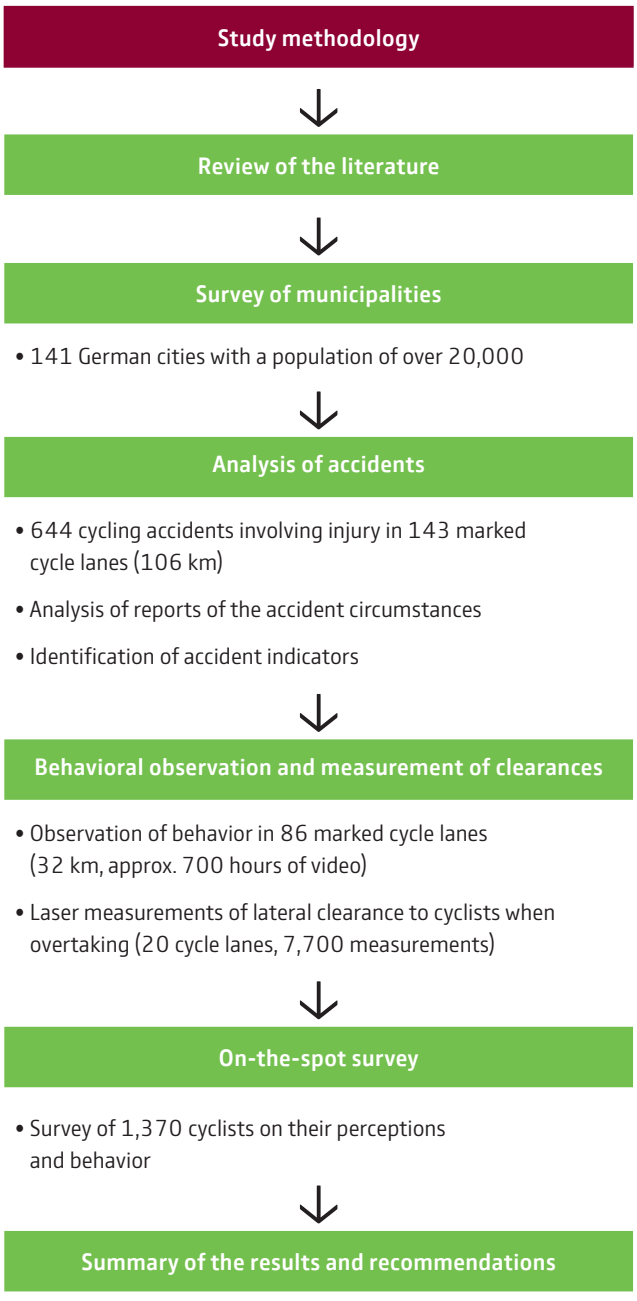


Figure 1: Study methodology

A comprehensive analysis of the accidents that occurred was conducted for the selected stretches of road. A total of 644 cycling accidents involving injury occurred on these stretches of road. In 174 cases, it was possible to analyze descriptions of the accident circumstances. For 406 accidents in Berlin, it was possible to analyze the circumstances of the accidents more closely based on the collision symbols used in the Berlin accident statistics. A comparison group of cycling accidents on main

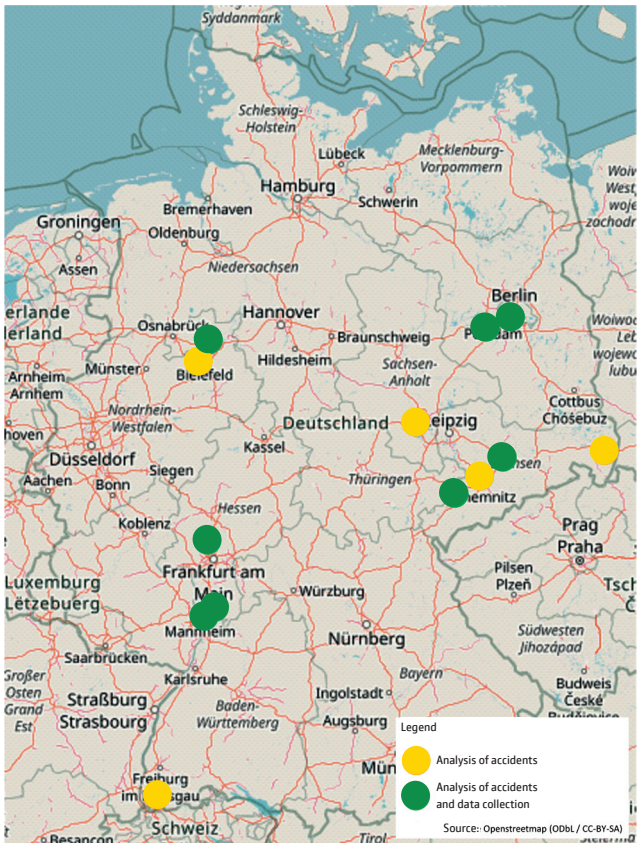


Figure 2: Locations of the stretches of road studied

roads in built-up areas ("HVS io") was also used to assess the results. This comparison group consisted of 15,900 cycling accidents involving injury on federal, state and district highways in built-up areas with a speed limit of 50 km/h in the federal states of Baden-Württemberg, Berlin, Bremen, Hamburg, Hesse, Saxony, Saxony-Anhalt and Thuringia from 2013 to 2015. In addition, for different sub-samples of the stretches of road studied, accident (cost) densities and accident (cost) rates were calculated. It was possible to calculate the accident (cost) densities for all stretches of road but accident (cost) rates for only 86 stretches of road by collecting data on the spot, since that was the only way to obtain the volume of cycling traffic as a reference parameter.

On a selection of 86 stretches of road (35 mandatory cycle lanes, 47 advisory cycle lanes and four "protected bike lanes" similar to those in the US and Australia), data was collected on the spot with the help of video in order to study both the behavior of cyclists and drivers and the conflicts that occurred. These stretches of road were between 240 m and 680 m in length and were observed in each case for a period of eight hours. This involved a total of around 32 km of road and almost 700 hours of video material.

The behavior of cyclists was examined at a representative cross-section of the stretches of road. In addition to other characteristics, the parts of the infrastructure used by the cyclists and their distance from the left-hand border marking (the motor traffic side) of the cycle lanes were recorded. The use of the mandatory and advisory cycle lanes by drivers was recorded over the whole length of the stretches of road studied. Distinctions were drawn between driving, stopping and parking, and the researchers recorded how long the drivers spent in the cycle lanes and their apparent reason for using them.

The conflicts that occurred involving cyclists were also recorded over the entire length of the stretches of road studied. The data recorded included the seriousness of the conflict, the cyclist's counterpart in the conflict, how the conflict arose and how the conflict was resolved. The conflicts were divided into minor conflicts, serious conflicts and accidents. Common to each of these conflict levels was a more or less critical situation. In other words, when cyclists had to take evasive, non-critical action to avoid stopping, stationary or parked vehicles, this was recorded merely as a hindrance. Consequently, it was possible to calculate the ratio of the number of hindrances to the number of incidents that were actually relevant to safety.

In addition, on 20 selected stretches of road in Berlin, a measurement bicycle belonging to Unfallanalyse Berlin was used to measure the clearance between overtaking motor vehicles and cyclists by means of a laser system. The type of the overtaking vehicle, the traffic

situation at the point of overtaking (with or without oncoming traffic) and the position of the measurement bicycle in the mandatory or advisory cycle lane were recorded. The clearances involved in a total of 7,688 overtaking cases were analyzed.

Furthermore, a total of 1,370 cyclists were surveyed on the 86 stretches of road studied. They answered questions about their behavior in traffic and what they thought about the marked cycle lanes that were being studied.

In the course of the project, the UDV also commissioned Prof. Dr. jur. Dieter Müller to produce a legal opinion on marked cycle lanes ("Rechtsgutachten zu markierten Radverkehrsführungen" [UDV 2018]). The purpose of this was to clarify when drivers would be justified in using advisory cycle lanes and what lateral clearance must be maintained when overtaking cyclists in marked mandatory and advisory cycle lanes.

Review of the literature

The use of marked cycle lanes on the roadway is described in detail in the General Administrative Regulations of the Road Traffic Regulations (VwV-StVO) and the German guidelines for the design of road infrastructure [above all, RASt 2006 and ERA 2010]. According to those, mandatory cycle lanes must generally be 1.85 m wide, including the marking, and be separated from the roadway for motor vehicles by a continuous line with a width of 0.25 m. Depending on the speed limit, they are recommended for roads with a traffic volume of around 1,000 to 1,800 motor vehicles an hour. Advisory cycle lanes, on the other hand, should have a standard width of 1.5 m and be separated from the part of the roadway intended for motor vehicles by a broken line with a width of 0.125 m. They are recommended on roads with traffic volumes of up to 1,000 trucks a day and around 400 to 1,000 motor vehicles an hour, depending on the speed limit. However, the guidelines currently do still permit smaller widths for both types of lane. Thus, in exceptional cases, mandatory cycle lanes only 1.5 m wide and advisory cycle lanes only 1.25 m wide are permitted.

Alongside parking strips, there must also be a safety strip with a width of 0.50 m to 0.75 m next to a mandatory cycle lane. In the case of advisory cycle lanes, the guidelines currently require this only when they are alongside parking strips where there is frequent parking activity.

If mandatory cycle lanes are created on roads with heavy motor traffic, the VwV-StVO regulations stipulate that they must be wider than usual or that there must be an additional safety space between the lane and the motor traffic.

Marked cycle lanes are also used in other countries but, based on the material examined in the study, not to the extent that they are in Germany. Whereas mandatory cycle lanes are also used in most of the other countries studied, advisory cycle lanes are rarer. The threshold for the traffic volume at which cycle lanes are to be used on the roadway is generally stricter in other countries. The guidelines in traditionally strong cycling nations such as Denmark or the Netherlands, above all, recommend that cycling traffic should keep to the sidewalk as of significantly lower motor traffic volumes.

The widths of the lanes in the different countries studied are similar. Mandatory cycle lanes including their markings must be between 1.50 m and 2.00 m wide in almost every country. In the Netherlands, however, mandatory cycle lanes with a width of up to 2.50 m are also recommended. The standard widths of advisory cycle lanes internationally are between 1.50 m and 2.00 m. With a standard width of 1.50 m, Germany is at the lower end of the range. In most countries, mandatory and advisory cycle lanes next to strips of parking spaces are separated from them by an additional safety strip with a width of 0.50 m to 0.75 m.

A number of older studies provide information on the safety level of marked cycle lanes. According to Alrutz et al. (2009), advisory cycle lanes away from signal-controlled intersections have lower accident (cost) rates than mandatory cycle lanes or cycle paths (based on the volume of cycling traffic). However, a disproportionately large number of accidents in connection with parking were found to occur in advisory cycle lanes. In addition, cyclists were found to be hindered by other road users significantly more often in advisory cycle lanes than in mandatory cycle lanes. Parkin and Meyers (2009) found

in the UK that marked cycle lanes can also result in narrower lateral clearances between cyclists and overtaking vehicles than in mixed traffic and can therefore also have a negative impact. Ohm et al. (2015) demonstrated that advisory cycle lanes had a positive impact on both the level of acceptance for cyclists on the roadway and the level of severity of the accidents.

There have been a small number of studies of alternative forms of lane for cycles, such as the protected bike lanes found in the US and Australia, but as yet no specific studies of their impact on safety.

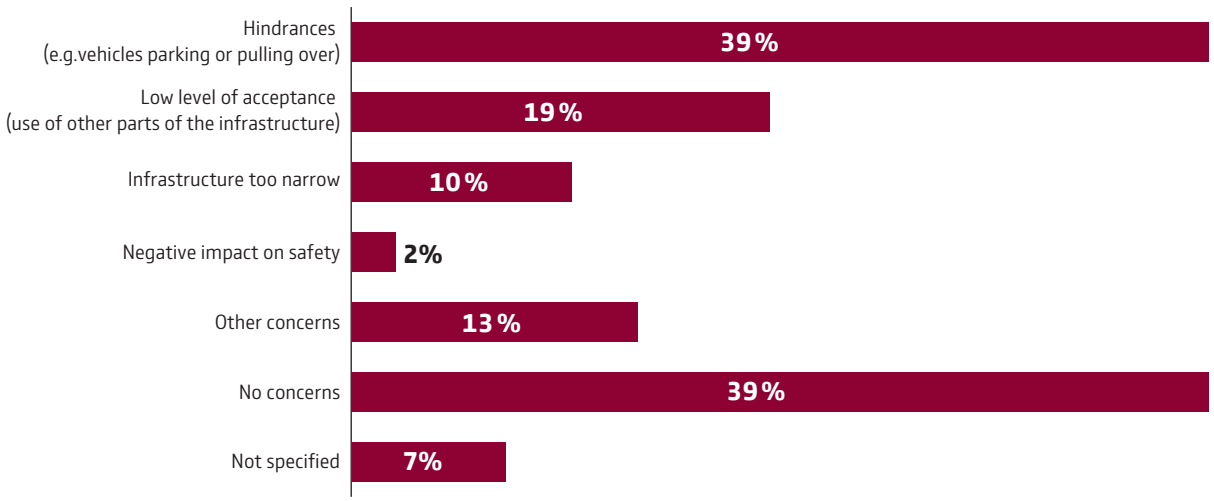
Survey of municipalities

The 141 responses from municipalities showed that both types of cycle lanes are very widespread. Advisory cycle lanes are even more common than mandatory cycle lanes. The results of the survey provided a mixed picture in terms of the width and markings of the two types of cycle lanes. According to the information provided by the municipalities, their cycle lanes largely met the requirements of the VwV-StVO and the design guidelines. However, they were also deviations from these, presumably based on earlier recommendations such as ERA 1995. Accordingly, there are currently still many facilities that no longer meet the current recommendations in the guidelines. The shortcomings of these facilities are, above all, that they are too narrow and that there are either no safety strips separating them from parked vehicles, or the safety strips are too narrow.

The municipalities' assessments of marked cycle lanes were largely positive. Only a few municipalities stated that they had any negative impact on road safety (figure 3). In contrast, however, users very often expressed their concerns about safety to the municipalities (figure 4). Consequently, many municipalities also reported that the level of acceptance of cycle lanes among cyclists was low. A further problem often referred to by both users and the municipalities themselves was that cycling traffic in the cycle lanes was often hindered by motor vehicles stopping or parking.

Frequent hindrances to cyclists caused by vehicles parking, pulling over, etc.

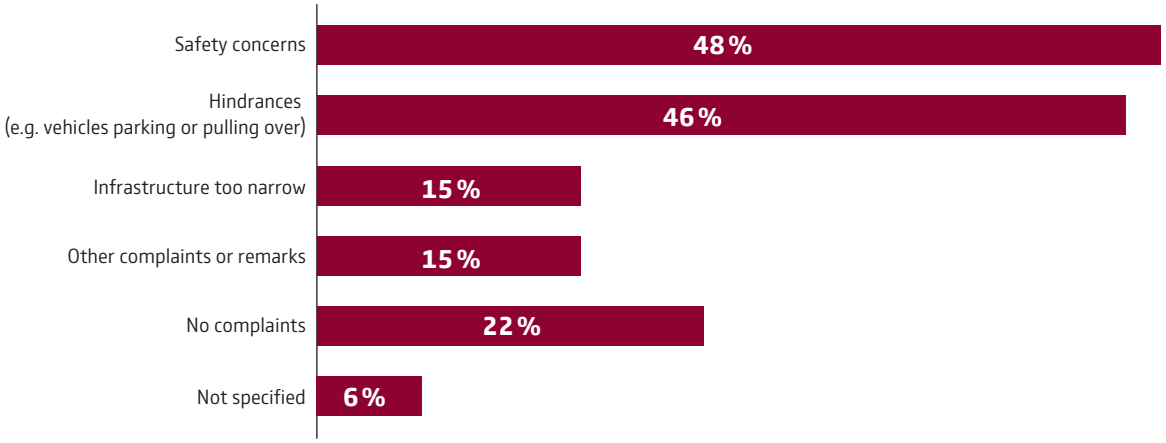
Figure 3 · **Concerns reported by municipalities**



n=119 municipalities (multiple responses possible)

Frequent safety concerns of users

Figure 4 · **Complaints reported to the municipalities by users**



n=119 municipalities (multiple responses possible)

Analysis of accidents

Around 60 percent of cycling accidents involving injury in both types of cycle lanes happened at intersections and T-junctions, particularly the typical turning-off, turning-into or crossing accidents (86 % for mandatory cycle lanes and 83 % for advisory cycle lanes; see figure 5). The proportion of these accidents in the marked cycle lanes corresponds roughly to that at the intersections of the comparison group of main roads in built-up areas (87 %). The very high proportion of turning-off accidents in the marked cycle lanes stood out (48 % for mandatory cycle lanes and 47 % for advisory cycle lanes). There was insufficient data to determine conclusively whether these higher proportions can be explained by higher volumes of traffic turning off the road or by lower volumes of traffic turning into or crossing the road on the stretches of road studied.

On the stretches of road with the marked cycle lanes, many accidents away from intersections occurred in connection with parking (figure 6). This was particularly true in the case of advisory cycle lanes. One in three accidents on the stretches of road with advisory cycle lanes were in connection with parking (33 %). In the mandatory cycle lanes, parking/parked vehicles were involved in 11 percent of accidents, whereas in the comparison group of main roads in built-up areas the figure was only 6 percent. The analysis of the circumstances of the accidents revealed that at least 65 percent of the accidents that occurred in connection with parking were caused by vehicle doors being opened (“dooring” accidents).

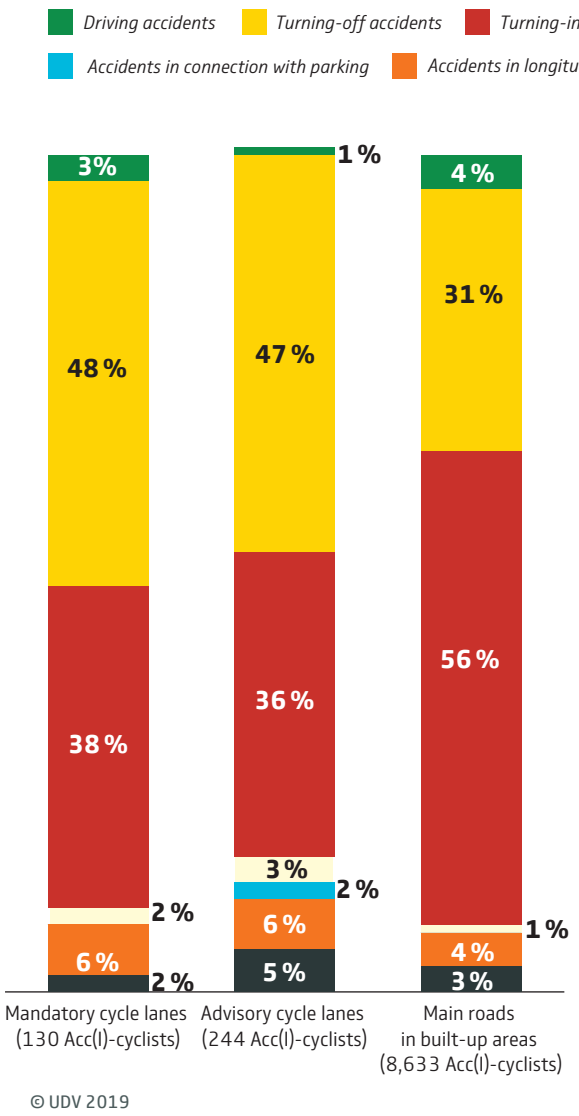
The significant role played by parking in the accidents in advisory cycle lanes was also evident in the accident statistics. The accident density on stretches of road with advisory cycle lanes with adjacent parking was almost four times as high as for advisory cycle lanes without adjacent parking (figure 7).

In order to assess the accident risk on the stretches of road studied, as part of the behavioral observation, traffic counts were conducted of the cycling traffic, and the corresponding accident rates were calculated. There was a strongly increased accident risk for cyclists particularly in narrow lanes (figure 8) and again on stretches of road with adjacent parking (figure 9).

In particular, lanes with less than the standard widths stipulated in the guidelines (under 1.85 m for mandatory cycle lanes and under 1.5 m for advisory cycle lanes) had particularly high accident rates. The advisory cycle lanes with the lowest accident rates were at least 1.85 m wide.

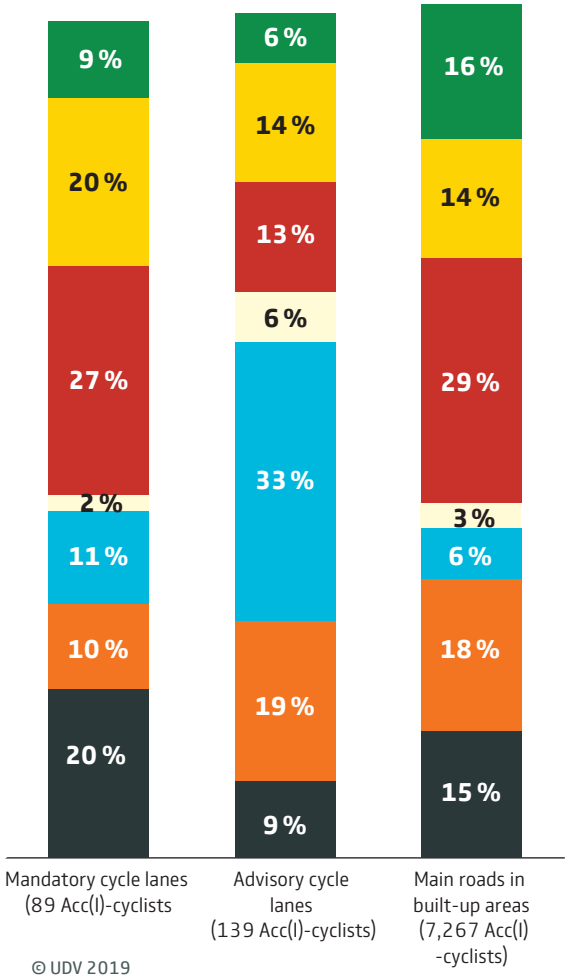
Many turning-off accidents at intersections

Figure 5 · **Accident types at intersections**



Many accidents in connection with parking on stretches of road

Figure 6 · **Accident types on stretches of road**

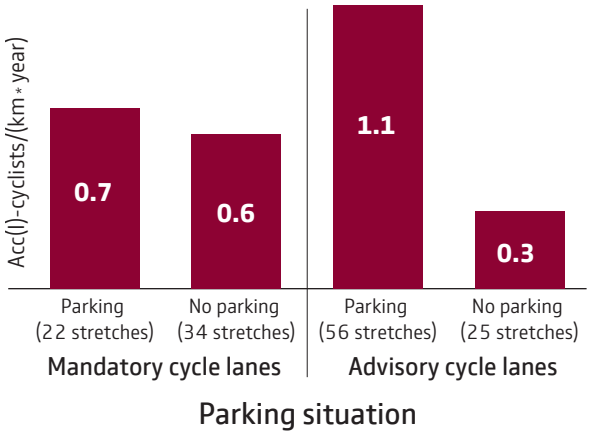


Mandatory cycle lanes with adjacent parking were found to be particularly unfavorable in the analysis of the accident rates. The accident risk for cyclists and mandatory cycle lanes with adjacent parking was more than twice as high as for stretches without adjacent parking (figure 9). Adjacent parking also had a negative impact, although not quite such a strong one, on the accident risk of cyclists in advisory cycle lanes.

No evidence was found for the negative impact of higher motor traffic volumes on the accident statistics.

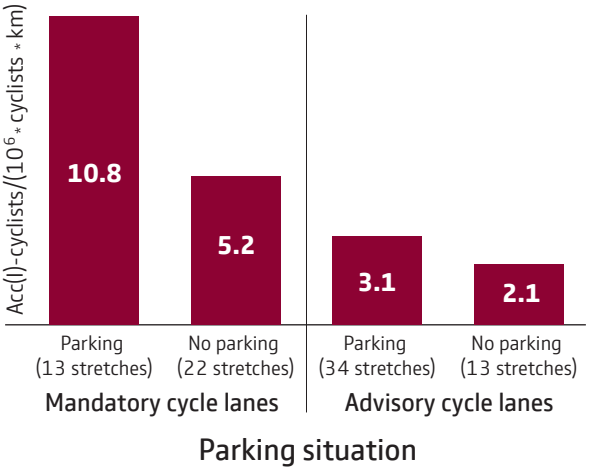
High accident densities in advisory cycle lanes with adjacent parking

Figure 7 **· Accident densities on the stretches of road, by parking situation**



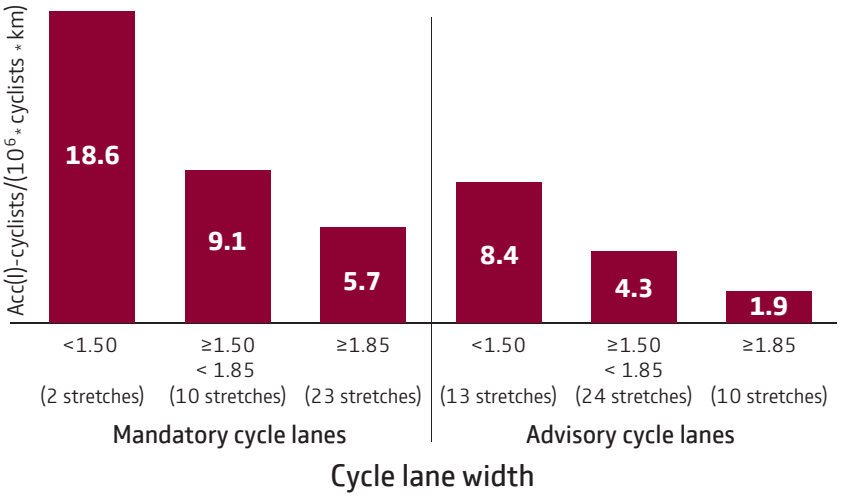
High accident risk on stretches of road with parking

Figure 9 **· Accident rates on the stretches of road, by parking situation**



Narrow cycle lanes are particularly unsafe

Figure 8 **· Accident rates on the stretches of road, by cycle lane width**



Behavioral observation

89 percent of the cyclists observed were cycling in the marked cycle lanes, as required by the rules. Violations of the rules almost always involved cyclists cycling on the sidewalk at the side of the road. No negative effects of motor traffic volumes in terms of the parts of the road infrastructure used were ascertained during the behavioral observation part of the study. However, the analysis of the accidents revealed that 70 percent of those in which the cyclists were found to be violating the rules in the cycle lanes occurred on stretches of road with a high volume of motor traffic (over 10,000 vehicles a day).

The width of the lane was observed to have a significant effect on the parts of the infrastructure used by the cyclists. The narrower the lane, the more frequently they violated the rules and used the sidewalk (figure 10). Cyclists failed to use mandatory cycle lanes with less than the standard width of 1.85 m particularly often. Almost one in five cyclists cycled on the sidewalk in these cases. The proportion of cyclists cycling on the sidewalk in violation of the rules was also very high (19 %) for mandatory cycle lanes with adjacent parking.

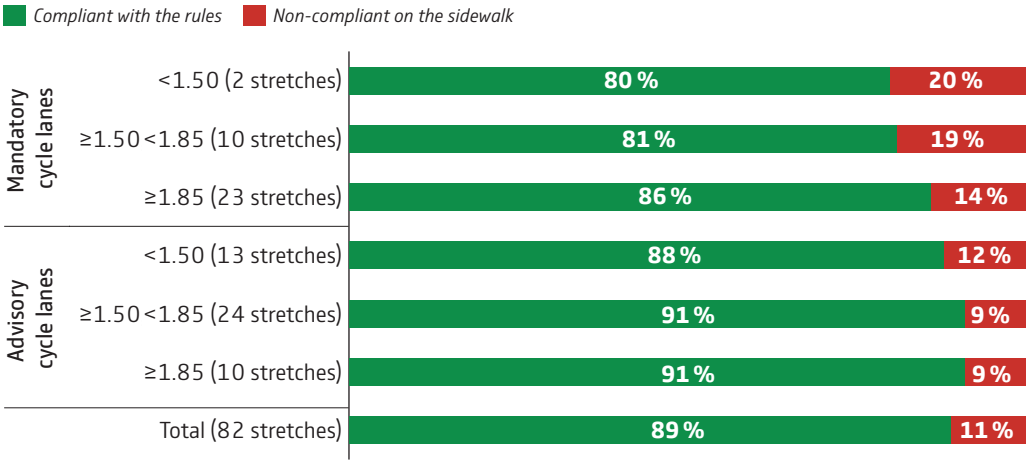
When cyclists used the lanes, they tended to cycle in the middle of them. At higher traffic volumes (more than 10,000 motor vehicles a day), the cyclists tended to cycle on the right in the lane and thus closer to parked vehicles. In narrow lanes, on the other hand, they cycled on the left in the lane and thus closer to the motor traffic (figure 11). Parked vehicles to the right of the lane had no effect on the line taken by the cyclists within the lane.

Many drivers used the cycle lanes for stopping or parking. During the 688-hour period of the study, vehicles parked in the lanes studied around 1,000 times and stopped almost 3,000 times. This happened very often in the advisory cycle lanes. Parking/parked vehicles hindered one in three (33 %) of over 25,000 cyclists here. If you add to this the number of hindrances caused by vehicles stopping legally, 39 percent of cyclists in the advisory cycle lanes were hindered by vehicles stopping or parking in these lanes. Vehicles parked in the mandatory cycle lanes significantly less often, but they also quite often stopped in these lanes. Stationary or parking/parked vehicles hindered around one in ten of the approximately 10,500 cyclists cycling in the mandatory cycle lanes.

In longitudinal traffic, as well, the markings of both types of lane were very often crossed by vehicles (not counting cases where vehicles were parking or pulling away after parking). With 173 cases per kilometer and hour for mandatory cycle lanes and 176 for advisory cycle lanes, the numbers for both types of cycle lane were almost identical. Mandatory cycle lanes were crossed quite often for short stretches, and advisory cycle lanes were

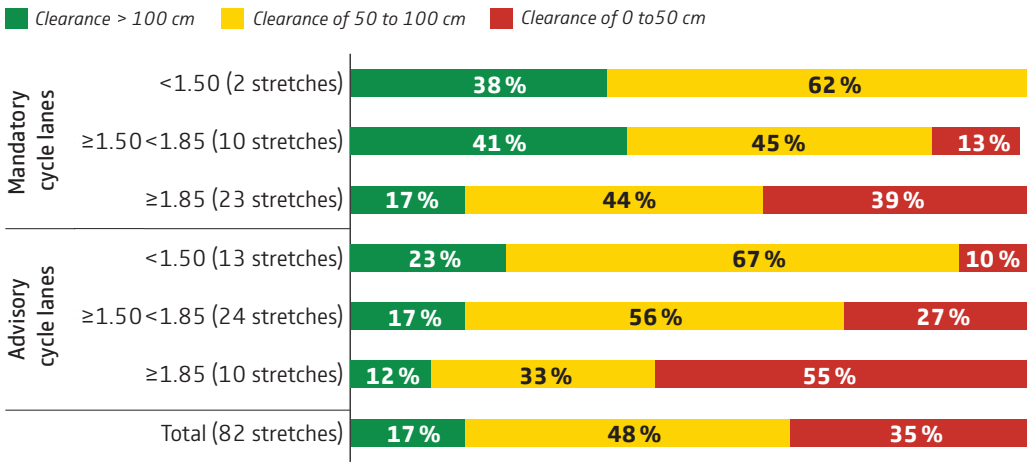
Cyclists often switch from narrow cycle lanes to the sidewalk

Figure 10 · **Part of the infrastructure used by cyclists, by cycle lane width**



In narrow lanes cyclists tend to keep to the left

Figure 11 · **Clearance of cyclists (wheels) from the left-hand lane marking, by width of the marked cycle lane**



also often crossed for longer stretches. Drivers mostly crossed the markings when there was no cyclist present. It was thus relatively rare for them to hinder cyclists. Less than 1 percent of cyclists were hindered in mandatory cycle lanes, whereas just over 2 percent were hindered in advisory cycle lanes. Drivers were observed using the lanes for a significant stretch of road, above all, when avoiding oncoming traffic, looking for a parking space or before turning off the road. When avoiding oncoming traffic, drivers often remained in the cycle lane for significantly longer than was necessary.

In the analysis of conflicts, a total of 154 conflicts were identified in the marked cycle lanes. Around 7 percent of these conflicts were serious. There was also one accident involving a pedestrian. Around 70 percent of the conflicts in the cycle lanes were caused by drivers' errors or inappropriate actions. Around a third of the conflicts were caused by vehicles stopping, parking or driving in these lanes. Nearly a further third of the conflicts were with vehicles that were turning off the road (27 %). 8 percent of the conflicts happened when vehicles were parking or leaving a parking space or when their doors were opened (dooring accidents).

27 percent of the conflicts were due to cyclists' errors or inappropriate actions. However, these were often also incorrect reactions to a preceding error or inappropriate action of a driver. In 17 percent of the conflicts, for example, cyclists failed to take into account the traffic behind them in the lane for motor vehicles when overtaking vehicles parked in the cycle lane, resulting in a conflict. The illegally parked vehicles in these cases contributed at least indirectly to the subsequent error or inappropriate action of the cyclists (figure 12).

Figure 12: Conflict between a cyclist and a stationary vehicle in the cycle lane

Measurement of clearances

In the approximately 7,700 cases in which the lateral clearance was measured between an overtaking vehicle and a cyclist in a marked cycle lane, the lateral clearance for almost one in two vehicles was found to be less than 150 cm. 15 percent of drivers maintained a lateral clearance of less than 100 cm when overtaking, and almost 1 percent maintained a lateral clearance of less than 50 cm. Trucks and buses drove very close to cyclists significantly more often when passing them. The clearance maintained from cyclists was very similar whether they were using mandatory cycle lanes or advisory cycle lanes. However, vehicles passed very close to cyclists a little more often when the cyclists were using mandatory cycle lanes (see tables 1 and 2).

Overtaking drivers were guided, above all, by the markings on the roadway. Even when the adjacent lane on the left-hand side or the lane for oncoming traffic was free, drivers still stayed very close to cyclists when overtaking. Often the drivers overtook the cyclists without leaving their own lane. The measurements of clearances also showed that the overtaking drivers did not react well enough to the position of the cyclists in the cycle lane. If the cyclist was in the left-hand half of the marked cycle lane, this resulted in lateral clearances that were 40 cm narrower on average

Cyclists were also often very close when they overtook each other. 11 percent of cyclists overtaking other cyclists in the cycle lane failed to maintain a lateral clearance of at least 50 cm. In advisory cycle lanes the clearances were on average around 10 cm narrower than in mandatory cycle lanes. In mandatory cycle lanes the position of the cyclist being overtaken was also observed to have consequences. If the cyclist being overtaken was in the left-hand half of the lane, the average clearance was around 10 cm narrower than for cyclists in the right-hand half of the lane. In contrast, this was

Lateral overtaking clearances to cyclists in mandatory cycle lanes

Table 1

Lateral overtaking clearance to the cyclist	Mandatory cycle lanes (n = 1,584 overtaking cases)					
	Motor vehicles					Bicycles
	Cars (n = 1,086)	Trucks (n = 42)	Buses (n = 14)	Two-wheel motor vehicles (n = 47)	Total (n = 1,189)	(n = 395)
Under 150 cm	51%	69%	43%	15%	50%	93%
Under 100 cm	19%	24%	21%	6%	19%	68%
Under 50 cm	0.4%	0%	0%	0%	0.4%	6.6%
Narrowest clearance	30 cm	55 cm	70 cm	85 cm	30 cm	17 cm

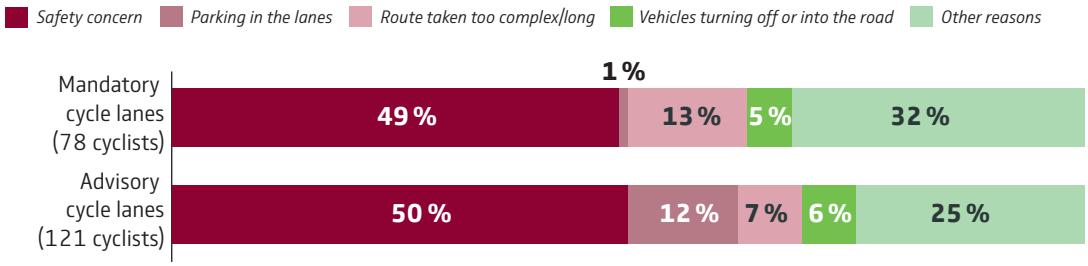
Lateral overtaking clearances to cyclists in advisory cycle lanes

Table 2

Lateral overtaking clearance to the cyclist	Advisory cycle lanes (n = 6,104 overtaking cases)					
	Motor vehicles					Bicycles
	Cars (n = 4,835)	Trucks (n = 95)	Buses (n = 27)	Two-wheel motor vehicles (n = 194)	Total (n = 5,151)	(n = 953)
Under 150 cm	48%	69%	89%	30%	48%	93%
Under 100 cm	14%	20%	44%	7%	14%	71%
Under 50 cm	0.8%	4.2%	7.4%	0.5%	0.9%	12.7%
Narrowest clearance	14 cm	12 cm	35 cm	30 cm	12 cm	5 cm

General safety concerns of cyclists

Figure 13 · **Reasons given by cyclists for not using the cycle lanes**



not observed in advisory cycle lanes. The clearances between cyclists during overtaking were particularly narrow, above all, when the overtaking cyclist tried to remain within the cycle lane.

Survey of cyclists

When the cyclists were surveyed on the spot, they rated mandatory cycle lanes as somewhat safer than advisory cycle lanes. Advisory cycle lanes narrower than the standard width of 1.50 m, in particular, were rated as less safe.

37 percent of cyclists in mandatory cycle lanes and 42 percent in advisory cycle lanes who rated them as unsafe stated that the reason was the narrow clearance to overtaking motor vehicles. Being hindered by motor vehicles in the cycle lane was given as the reason by 12 percent and 18 percent, respectively. The danger from vehicle doors being opened (dooring), on the other hand, played only a minor role according to the cyclists surveyed (4 %).

Over a third of the cyclists rated the clearance of overtaking motor vehicles to cyclists in the cycle lanes as insufficient. In advisory cycle lanes narrower than the standard width of 1.50 m, that rose to 46 percent of the cyclists.

Most cyclists stated that they generally used the marked lanes (83 %). It was again found that cyclists avoided lanes narrower than the standard width (under 1.85 m for mandatory cycle lanes and under 1.5 m for advisory cycle lanes) more often than lanes of the standard width. About one in four cyclists stated here that they generally used the sidewalk rather than the cycle lane. Most of the cyclists mentioned fundamental safety concerns as the reason for using the sidewalk, and in the case of advisory cycle lanes they also often mentioned being hindered by motor vehicles in the cycle lanes (figure 13).

Most of the cyclists stated that there was not enough space in the cycle lane for cyclists to overtake each other (42 % for mandatory cycle lanes and 49 % for advisory cycle lanes). Accordingly, very many cyclists also stated that they left the lane in order to overtake other cyclists. Although this is not allowed when using mandatory cycle lanes, 64 percent of the cyclists stated that they generally leave the lane when overtaking. 71 percent of the cyclists surveyed stated that they do this when using mandatory cycle lanes narrower than the standard width of 1.85 m.

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Legal opinion

In the legal opinion obtained by the UDV on marked cycle lanes [UDV 2018], the following two undefined legal phrases were evaluated: “the need of other vehicles to use advisory cycle lanes” and “the required lateral clearance when overtaking cyclists using mandatory and advisory cycle lanes”.

According to the legal opinion, drivers are not considered to "need" to cross over into a marked advisory cycle lane unless they have to do it to avoid oncoming vehicles. Other scenarios, such as the use of the advisory cycle lane to turn off to the right or to pass vehicles that are stopping for traffic, do not constitute a need to use the advisory cycle lane, according to the legal opinion.

With regard to the required lateral clearance when overtaking cyclists in marked mandatory and advisory

cycle lanes, the legal opinion concludes: "In accordance with the relevant case law and the fundamental principle of road safety being the uppermost maxim when interpreting the stipulations of the German Road Traffic Regulations (StVO), a minimum lateral clearance of 1.5 meters must be maintained when overtaking or passing cyclists, regardless of the prescribed type of cycling facility. If this cannot be maintained, drivers are effectively prohibited from overtaking, pursuant to section 5, paragraph 4, sentence 2 of the German Road Traffic Regulations (StVO)."

Summary

As the study shows, mandatory and advisory cycle lanes are already very widespread in Germany. In addition to many cycle lanes that comply with the guidelines, however, there are also many that do not adhere to the recommendations in the current guidelines. Many municipalities and cyclists complain that cyclists are frequently hindered in cycle lanes by vehicles stopping or parking. Many cyclists do not feel safe in marked cycle lanes. Cyclists frequently avoid using narrow lanes, in particular, and prefer to use the sidewalk instead. Cyclists generally cycle in the center of the cycle lanes, a little further to the left in narrow lanes and a little further to the right when there is a high volume of motor traffic. Parked vehicles to the right of the cycle lane had no effect on the line taken by the cyclists.

Many drivers were observed using the cycle lanes for stopping or parking. Nearly 30 percent of the more than 35,000 cyclists observed in the study were hindered in their progress in the cycle lanes as a result of this. Vehicles also often cross into the cycle lanes in longitudinal traffic, but this rarely hinders cyclists. A third of the conflicts observed were caused by drivers stopping, parking or driving in these lanes. Almost a further third of the conflicts were with vehicles turning off the road, and 8 percent were caused by drivers parking or leaving parking spaces or by vehicle doors being opened.

When overtaking cyclists in mandatory and advisory cycle lanes, almost one in two drivers failed to maintain a lateral clearance of 150 cm. 15 percent of drivers maintained a clearance of less than 100 cm when overtaking, and almost 1 percent maintained a clearance of less than 50 cm. Overtaking drivers were guided, above all, by the markings on the roadway. They also reacted only inadequately to the position of the cyclists in the cycle lanes. Even when the adjacent lane on the left-hand side or the lane for oncoming traffic was free, drivers still stayed very close to cyclists when overtaking. Often the drivers overtook the cyclists without leaving their own lane. In the survey of cyclists, many of them stated that the clearance between them and overtaking vehicles was narrow. Cyclists were also often very close when they overtook each other. The clearances were found to be particularly narrow when cyclists tried to overtake each other within their lane. The survey of road users confirmed these results.

At intersections in the course of marked cycle lanes, the typical turning-off, turning-into and crossing accidents occurred, above all. On the free stretches of road with the marked cycle lanes, many accidents occurred in connection with parking. Many were caused when vehicle doors were opened. The significant role played by parking in the cycling accidents that occurred in advisory cycle lanes was also evident in the accident statistics. A high risk of accidents was found, in particular, for narrow cycle lanes and for cycle lanes with adjacent parking spaces.

Recommendations

Due to the large number of related accidents, the UDV recommends the mandatory marking of safety strips with a width of 0.75 m separating both mandatory and advisory cycle lanes from parking strips. To ensure an adequate safety clearance to passing vehicles, mandatory cycle lanes should also (like cycle paths) have a safety strip of 0.75 m separating them from the part of the roadway used by motor vehicles. In locations without parking spaces, this could also be implemented as a hatched area.

The current width specifications for marked cycle lanes must also be reconsidered. In particular, the minimum width of 1.25 m stipulated in the guidelines for advisory cycle lanes is completely inadequate and should no longer be used. Advisory cycle lanes should have a width of at least 1.5 m even in the case of well-justified exceptions. Given the findings about clearances when

overtaking, the different required widths for advisory and mandatory cycle lanes can no longer be justified from a road safety perspective. The UDV therefore recommends a standard width of 1.85 m for both advisory and mandatory cycle lanes. In fact, in order to enable cyclists in mandatory cycle lanes to overtake safely within the marking, widths of at least 2.25 m (including the marking on the left) are required, because cyclists are not allowed to leave the lane even when overtaking (as in the case of cycle paths).

When advisory cycle lanes are created, the width of the roadway remaining for motor vehicles must be at least 5.0 m. In accordance with Section 2 of the German General Administrative Regulations of the Road Traffic Regulations (VwV-StVO), "the remaining part of the roadway not taken up by the advisory cycle lane ... must be wide enough to allow two cars moving in opposite directions to pass each other without any danger". Given that the broken line of advisory cycle lanes should be crossed only in exceptional cases according to the regulations [see UDV 2018], the width currently specified in the guidelines for the part of the roadway not taken up by the advisory cycle lane is inadequate. Even with narrow overtaking clearances, the widths of current vehicles require a roadway width (not counting advisory cycle lanes) of at least 5 m to provide enough space for oncoming traffic. For example, the width of the most common new car in Germany in 2018 (the Volkswagen Golf) is 2.027 m including its wing mirrors. Taking into account the space required for lateral movement and safety when there is oncoming traffic [see RASt 2006], the currently stipulated roadway width (not counting advisory cycle lanes) of 4.5 m is not enough to allow two of these common cars to pass each other.

Given the high number of violations of the rule against parking or stopping in marked cycle lanes and the resulting hindrances and risks for cyclists, these violations must also be rigorously monitored and penalized.

The legal opinion written on the subject states that it is necessary to define more closely the vague term "need" that is used in the German Road Traffic Regulations (StVO) in the context of crossing into advisory cycle lanes. Work also needs to be done to explain to road users the required safety clearance when passing or overtaking cyclists in marked cycle lanes (see UDV 2018 for more information).

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